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WOODS HOLE OCEANOGRAPHIC INSTITUTION
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A System for the Centralized Recording of Remotely Detected Seismic Data

by

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APPROVED FOR DISTRIBUTION J. B. Hersey

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Department of Geophysics

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ABSTRACT

This paper describes a system for the acquisition and recording of seismic data at a central location from several widely scattered detector sites on land. The system uses leased telephone lines and commercially available carrier equipment. The detectors and all associated equipment are described. This equipment was assembled to detect seismic waves from a series of large explosive shots conducted by the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, The University of Wisconsin, and the Woods Hole Oceanographic Institution during July of 1961.

INTRODUCTION

The system herein described was assembled at the Woods Hole Oceanographic Institution to detect explosive shots made at sea over the continental shelf at several widely separated shore stations. The decision to use a system in which the stations were unattended and tied to a central recording facility was dictated by several factors. In the three weeks available for design, construction, testing, and installation of the system it was not possible to get together enough personnel to man field sites to do independent recording. Radio links to the various stations were ruled out because of lack of 24-hour-per-day reliability as well as the problem, by no means small, of getting FCC frequency allocations on short notice. Completely automatic recording at each site would have been expensive. For the necessary timing accuracy either a recording of WWV or an extremely accurate internal clock would have been required. Moreover, no warning or indication of malfunction would be given unless it were discovered on a routine visit to the site affected.

The use of leased telephone lines for the data transmission was decided upon as the best all-around solution. Leased lines are available on very short notice from the telephone company. Offsetting the disadvantage of narrow bandwidth of a telephone system was the gain in reliability. To pass the desired data bandwidth over the telephone lines it was found necessary to adopt an FM system. Since the required information band was only dc to $<$100 cps a low carrier frequency could be used. A set of self-powered commercial equipment which had been designed for the transmission of electrocardiograms by telephone was acquired. It was small and light weight, had long battery life, and required no direct electrical connection to the telephone lines.

A survey to find existing deep wells which were not in use was conducted and seven sites were selected: Orient Point, L. I. (300 feet), Block Island, R. I. (250 feet), Martha's Vineyard, Mass. (125 feet); Nantucket, Mass. (30 feet); North Truro, Mass. (150 feet); Chatham, Mass. (100 feet); Sandwich, Mass. (250 feet); and Waquoit, Mass. (146 feet). All were 3-inch-cased wells except at the Nantucket site where, because of the low level of the area, only an open well was available.

After the stations were placed in operation, with hydrophones as detectors, it soon became obvious that an upper cutoff frequency below 5 cps would be necessary if large signals in the 6 - 7 cps range were to be eliminated. It was known that the expected seismic energy would appear above about 2 cps. The extremely unsophisticated seismometers (described below) were the

quickest solution available; with a resonance of approximately 4 cps they acted as much sharper low-pass filters than any purely electrical filter that could have been inserted.

The advantages of central real-time recording in seismic work are obvious. The difficult and often impossible task of correlating seismic events in time when they are detected at widely scattered points is solved as the real-time error is small (i. e. < 1 msec) for a station spread of 100 miles. If greater real-time accuracy is required, the various delays due to the transit times of the acoustic signal into and out of the telephone handset and the transit time of the signal through the telephone lines may be either measured or predicted to fair accuracy.

The system was arranged as shown in Fig. 1. All of the stations were connected in a similar manner. The change effected in detectors during the course of the experiment did not change the system arrangement. Each component is described in detail below.

SYSTEM DETAILS

Detectors.

Two types of detectors were used. The first consisted of a "watch fob" hydrophone element coupled to a special high input impedance preamplifier (Fig. 2). The hydrophone and preamplifier were assembled into a 2 1/2-inch OD brass pressure case which was then filled with Dow Corning DC-200 (20 cstokes) silicone oil. The oil fill provided a measure of protection against flooding, as water entering could only displace the small air pocket enclosed and would collect in the bottom of the pressure case. The electronics are arranged such that any water thus entering would be below the level of the electronics and would therefore not cause shorting. It was found, in fact, that one hydrophone-preamplifier assembly did admit some water in this way and its operation was not affected.

The transducer is a barium titanate element consisting of two disks with an air space between them. This type is used commonly in ASW sonobuoys and is readily available.

The preamplifier (Fig. 3) consists of a pair of RCA 7586 Nuvistors. The first stage acts as a cathode follower presenting approximately 75 megohms input impedance to the hydrophone. This high impedance makes possible the use of the hydrophone at frequencies of less than 1 cps. The second Nuvistor is a gain stage giving an amplification of about 20 db. The transistor line-driver provides the necessary impedance transformation to drive a line to the surface. It is essentially a double pair of Darlington-connected transistors operating from a split battery source. This battery also provides the necessary filament power for the Nuvistors.

The second detector system used was a torsion spring pendulum seismometer (Fig. 4) designed and built to minimize sensitivity at the higher frequencies (i. e. $>$ 5 cps). The pendulum was resonant at 4 cps. Directly attached to the arm of the pendulum was a simple ceramic phonograph cartridge. Crystal-type pickups, although more sensitive, would not stand the moisture encountered in the field. The cartridge was mounted rigidly to the base plate and attached through a rubber coupling to the pendulum arm through a 1-inch piece of No. 18 piano wire.

As would be expected, a detector such as this acts as an accelerometer below its natural resonant frequency and as a displacement sensor above it. The seismometer was followed by a 10 cps RC low-pass filter incorporated into the amplifier. No attempt was made to get an absolute calibration of the seismometer's sensitivity. It was sufficient to find that it was giving considerable output from many noise sources which were located and identified.

The seismometer fed a transistor preamplifier (Figs. 5a and 5b) which was essentially an impedance matching device. To give appreciable output from the cartridges at low frequencies they must work into a high impedance. A Darlington-connected preamplifier was used to provide the necessary impedance transformation before the line amplifier. Its input impedance was in excess of 2 megohms. No gain was necessary, because of the short cable run (i. e., 3 to 5 feet) to the line amplifier and transmitter assembly.

These seismometers were located on the well heads, as they were too large to be lowered into the well casings and no readily evident system would have allowed them to be rigidly mounted if they were lowered into the wells. It was felt that the well casings would act as a rigid probe at the low frequencies of interest.

Amplifiers.

In addition to the preamplifiers attendant to the two types of detectors, a line amplifier was used (Figs. 6a and 6b). It is a conventional RC-coupled transistor amplifier. It was found in practice that the first two stages were not needed, as the acoustic noise level in the wells was far higher than had been anticipated.

This amplifier uses a 2N207B transistor as a low-level low-noise front end stage. The 2N207B was selected because of its low noise and excellent linearity. The remaining stages all use 2N1309 transistors to bring the total gain up to 112 db. The amplifier broadband noise with 600-ohm input impedance is less than 1 μ volt. The amplifier 3 db bandwidth points are $<$1 cps to 15 kcps. The undistorted output voltage swing is ±10 volts from a source impedance of approximately 3 kilohms.

This amplifier brings the signal level up to the ±3-volt level required by the PFM transmitter.

All preamplifiers and amplifiers are powered by a dry battery stack. This stack provides a minimum of 7 days of unattended life with the hydrophones or 14 days with the pendulum seismometer.

PFM Transmitter.

The PFM transmitter is a commercially available unit originally designed for sending electrocardiograms by telephone. The unit contains its own 6-volt mercury battery which gives a continuous operating life in excess of 30 days.

The transmitter is essentially a voltage-controlled oscillator producing a series of identical pulses whose repetition rate is controlled by the input signal voltage. The center frequency rate is approximately 1600 pps and is shifted ±1000 by the input signal. This 600-to-2600 pps pulse train is used to drive a 2-inch permanent magnet speaker. The speaker acts as a low-pass filter producing an approximately sinusoidal acoustic signal.

The speaker is attached directly to the telephone handset and "talks to" the telephone. The band of frequencies generated falls well within the 300-to-3000 cps bandwidth of a typical telephone voice channel. Signal degradation

by passage through the telephone lines and repeaters was not detectable in the dc-100 cps information band.

All amplifiers, transmitters, and batteries were contained in plywood shelters. These shelters (Fig. 7, a-c) are vented, to prevent unnecessary heating in direct sunlight, yet provide adequate protection from rain.

Telephone System.

Lines were leased from the telephone company. These lines connected the remote sites to the WHOI recording station. The lines used were voice channels rather than what the telephone company refers to as "data lines". The fact that poles in most cases did not extend to the actual site necessitated the use of extension lines provided by WHOI. The telephone company requires that an instrument be placed at the end of their line. Since it was desired to operate by hand ringing they provided battery-operated hand-ringing wall-type telephones such as found in rural farmhouses. These were not satisfactory for the connection of the PFM transmitter, as the life of the No. 6 dry cells used was only a few days. It was found that Army type EE-8 field telephones whose battery life was about two weeks, were compatible with the system.

The restrictions on the levels and the audio fidelity in the telephone system made the use of the PFM system virtually mandatory. The frequency range of the typical repeater amplifier is approximately 300 to 3000 cps. This range is of no use for seismic purposes. The additional restriction on dynamic range, that it must remain above the line noise level and yet stay below the +6 dbm level which would cause crosstalk, would have reduced the information range too much. The PFM system operates at constant line level and is not affected by any but the loudest of line noises.

The fact that the PFM system having a loudspeaker "talking to" the telephone does not require an electrical connection to the telephone lines eliminates a problem posed by the fact that the telephone company requires that all devices connected to their lines be approved by them. Since the telephone handset is virtually incapable of exceeding the allowable line level there is no problem of crosstalk. The carbon microphone also acts as a bandpass filter, preventing undesirable frequencies from getting into the lines.

At the terminal end of each line a wall-type telephone was installed for each line. Once again no electrical connection was required, so no difficulties were encountered with line levels. A microphone was placed on each telephone receiver in such a manner that it could be easily removed for voice communication. A ringing generator was provided for ringing any of the field sites. Ringing from the field sites was done by hand magneto both in the EE-8 telephone and in the magneto sets provided by the telephone company.

The fact that voice communications were possible from each site to the central recording station simplified the problems of gain adjustment and testing. Data-type lines normally do not provide voice communications capability.

Central Receiving and Recording Station.

Little need be said about the station equipment (Fig. 7d) since, with the exception of the PFM receivers, the instrumentation was conventional in that thermal-writing multichannel recorders are used.

The PFM receiver-demodulator units are connected by means of a sensitive crystal microphone to each telephone handset. Carrier lock-on is indicated by a meter on each unit. Erratic movement of this meter indicates insufficient line level for a good lock. In addition, low-frequency signals may be seen on the meters. The output of the receiver-demodulators is fed to the recorder amplifier and thence displayed on the recording paper.

The only precaution necessary is that silence be observed during recording periods. Since there are speech frequencies within the range of the receiver-demodulators they can be upset by loud talking near the microphones.

Summary.

The field sites were instrumented with no particular care taken for weather protection other than the use of plywood enclosures. Temperatures ranging from 55 to 95 °F were encountered, as well as rain, wind, and fog. So far as is determinable no adverse effects resulted. Early morning dew more often than not drenched the equipment and was dissipated by the noonday sun.

The battery life was sufficient to allow a single team to make the rounds for battery replacement and general maintainence. It is worthwhile to point out here that, had time allowed, a considerable saving in battery power could have been accomplished by turning the equipment on and off from the central location by use of the ringing voltage.

The system as used was by no means a finished product. Rather, it was the product of a hurried development program extending over only a very few weeks. It is hoped that these notes will provide a starting point for further use of remote detection systems wherein seismic data may be gathered in real time from many widely separated locations.

ACKNOWLEDGMENTS

This equipment was designed for use in a seismic experiment under the direction of Dr. John W. Graham of Woods Hole Oceanographic Institution. The assistance of Mr. Willard Dow in the preamplifier design is gratefully acknowledged. The assistance of Mr. Stanley Eldridge in the fabrication of the instrument housings is also gratefully acknowledged. The rapid installation and service of the station would have been impossible without the assistance of our pilot, Mr. Robert G. Weeks. This work was funded under Office of Naval Research Contract Nonr-1367.

REFERENCES

DeWitt, D., and Rossoff, A. L., 1957. Transistor Electronics, McGraw-Hill, New York.

Terman, F. E., 1955. Electronic and Radio Engineering, 4th ed., McGraw-Hill, New York.

For information concerning the scientific program for which this equipment was developed see:

Meyer, R. P., Steinhart, J. S., Howell, B. F., Jr., Bonini, W. E., Fahlquist, D. A., and Aldrich, L. T., "Cooperative Maine experiments in crustal seismology: Method and application of fixed linear recording arrays to crustal measurements", Abstracts, 43rd Annual Meeting, A. G. U., 25-28 April 1962, Washington, D. C.

Steinhart, J. S., Meyer, R. P., Howell, B. F., Fahlquist, D. A., Bowini, W. E., and Asada, T., "Maine seismic experiment: General crustal results", Abstracts, 43rd Annual Meeting, A. G. U., 25-28 April 1962, Washington, D. C.

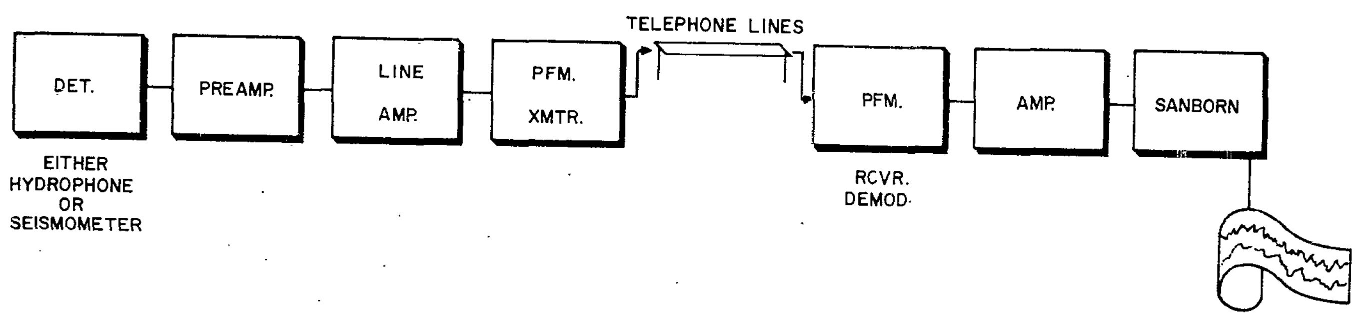


FIG. 1. SYSTEM BLOCK DIAGRAM.

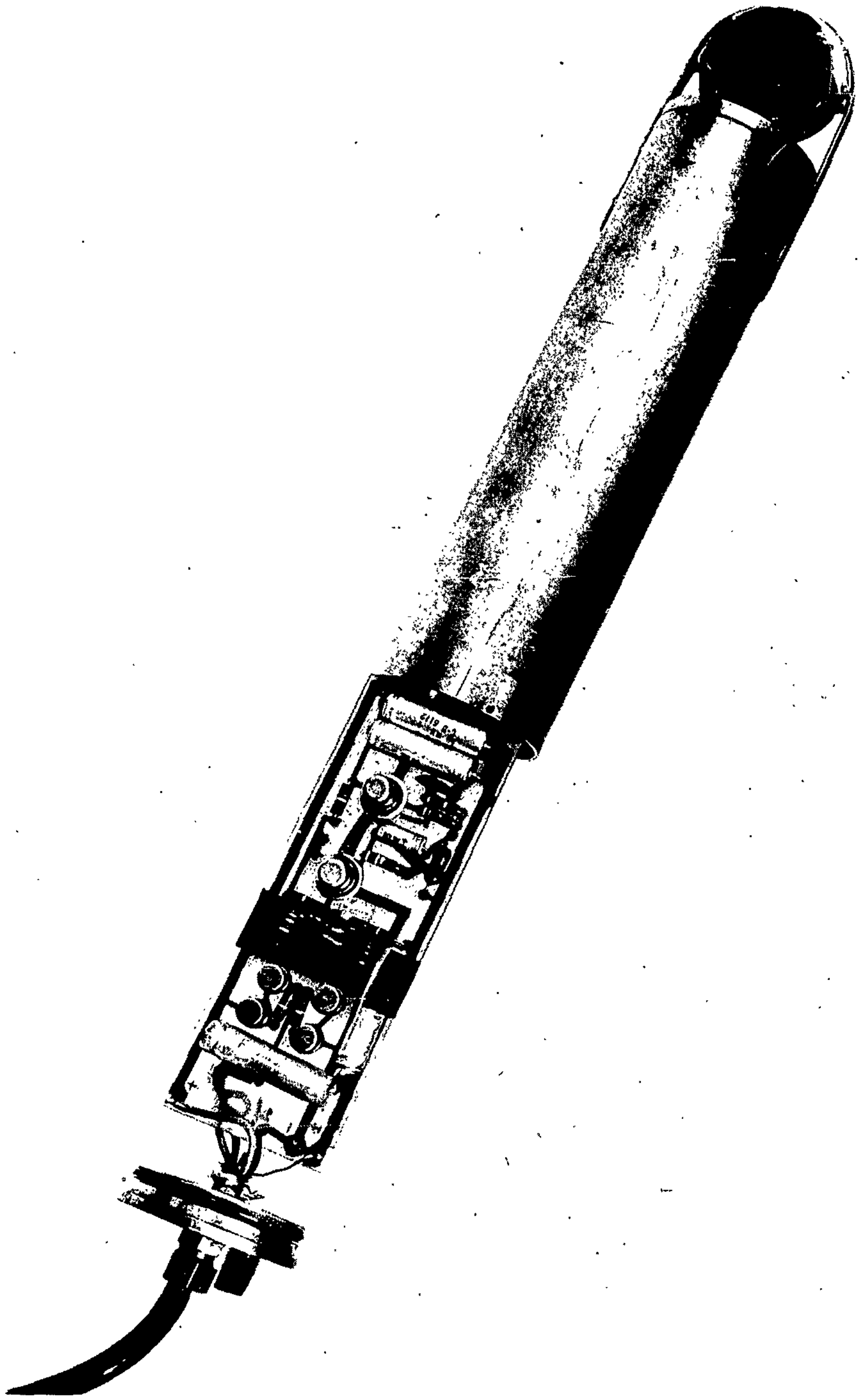


FIG. 2. "WATCH FOB" HYDROPHONE AND PREAMPLIFIER OPENED TO SHOW PREAMPLIFIER CIRCUIT BOARD.

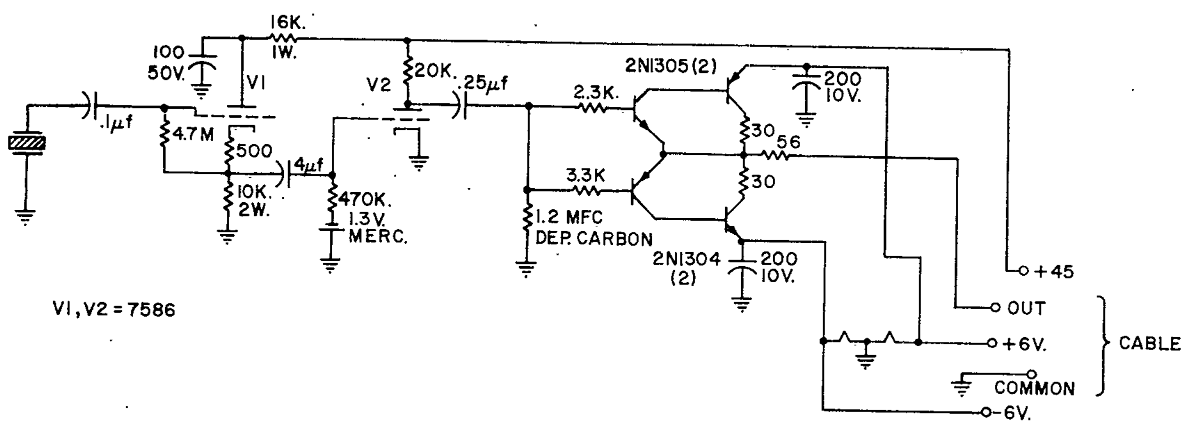


FIG. 3. "WATCH FOB" HYDROPHONE PREAMPLIFIER.

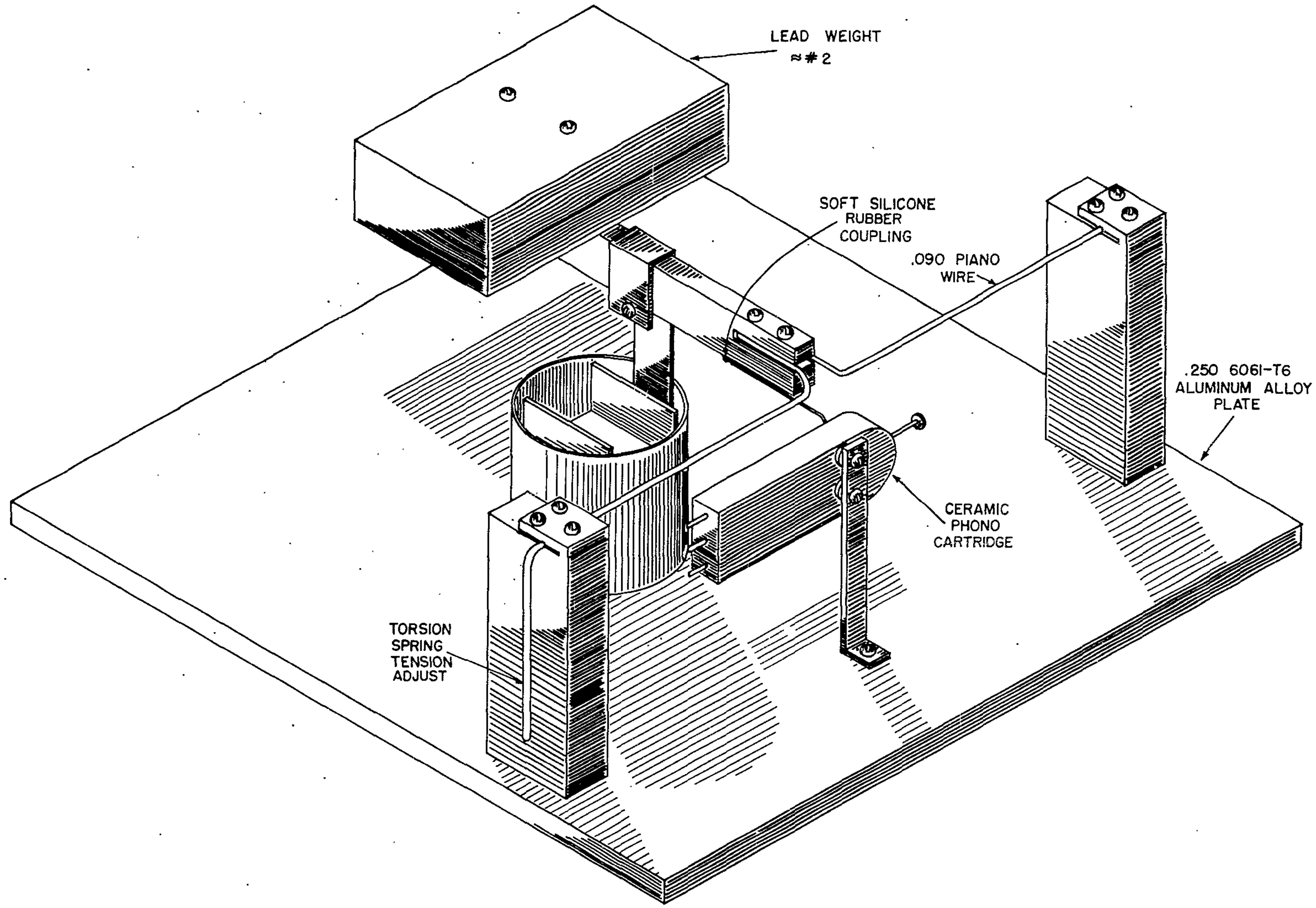


FIG. 4. TORSION PENDULUM SEISMOMETER.

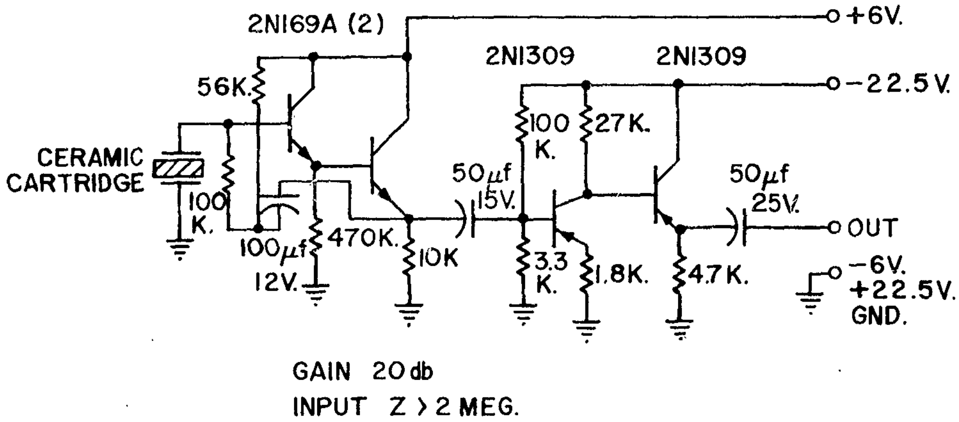
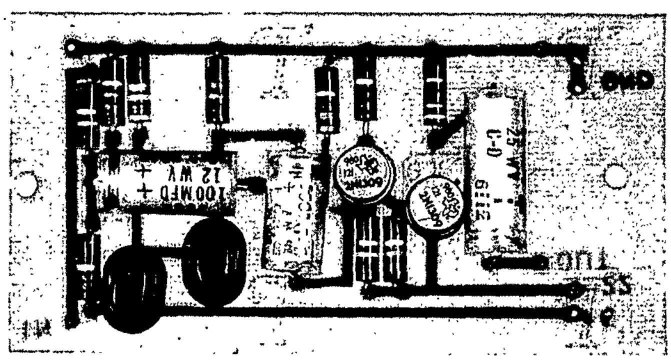


FIG. 5a. SEISMOMETER PREAMPLIFIER.



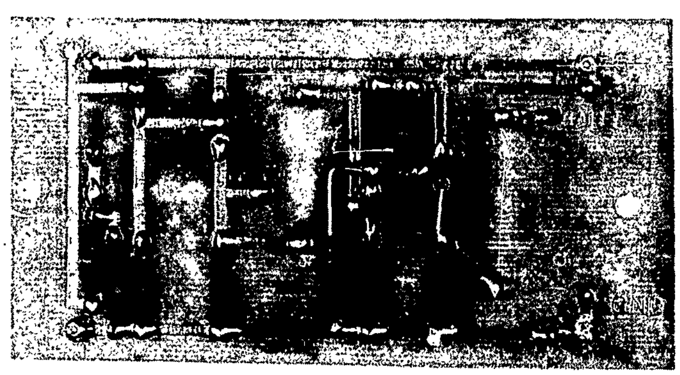
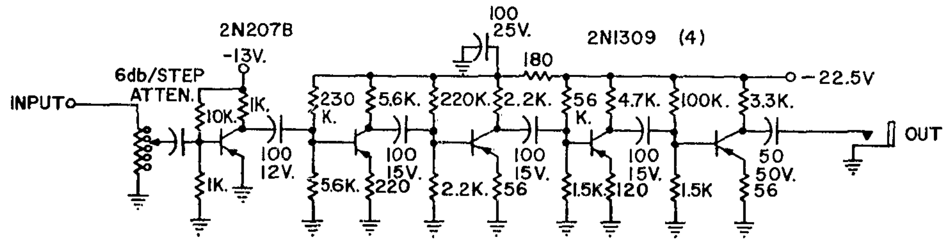


FIG. 5b. SEISMOMETER PREAMPLIFIER PRINTED CIRCUIT BOARD.



≈ 112 db GAIN

< 1μV. NOISE

1/2 ~ TO 15 Kc/S

FIG. 6a. LINE-DRIVER AMPLIFIER.

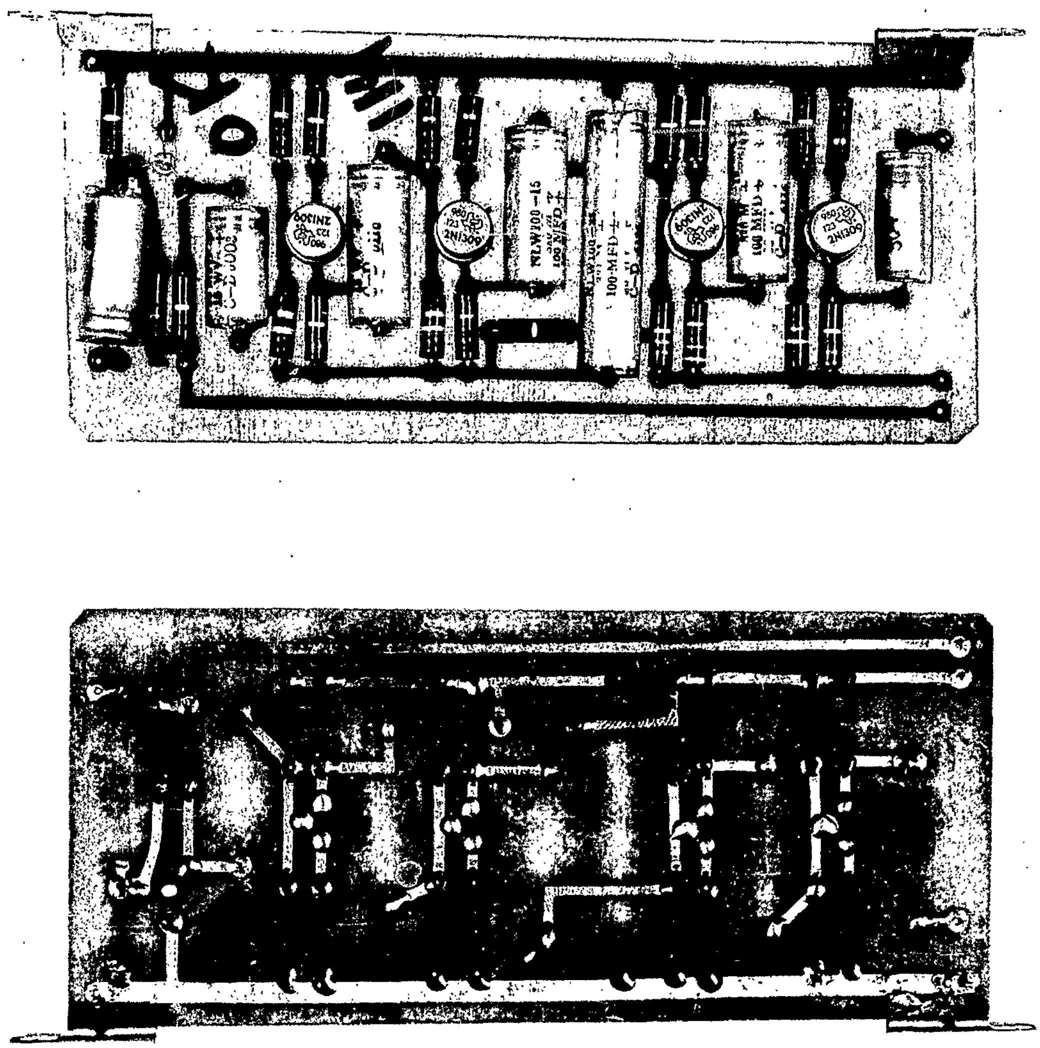


FIG. 6b. LINE AMPLIFIER PRINTED CIRCUIT BOARD.

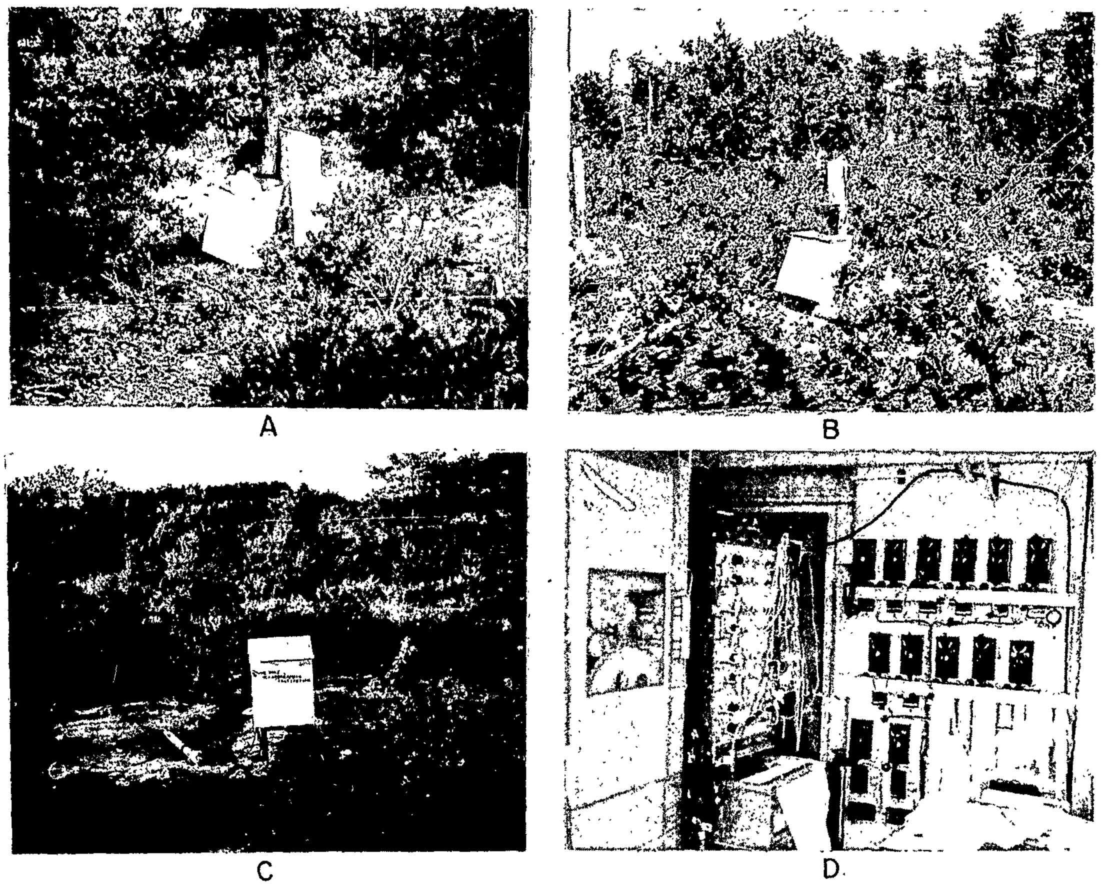


FIG. 7. (A, B, C) TYPICAL FIELD SITES
(D) CENTRAL RECEIVING STATION.

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